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SECRETARY

ENERGY AND ENVIRONMENT CABINET
DEPARTMENT FOR ENVIRONMENTAL PROTECTION
DIVISION OF WATER
200 FAIR OAKS LANE, 4TH FLOOR
FRANKFORT KENTUCKY 40601
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January 18, 2011

Northern KY Water District
Attn: Amy Kramer, Design Engineering Manager
2835 Crescent Springs Road
P.O. Box 18640
Erlanger, KY 41018

RE: Northern Kentucky Water District
AI # 2485; PWSID # 0590220
WX: 21227208
Advanced Treatment Project
FTWTP, MPWTP & TMWTP

Dear Ms. Kramer:

Thank you for submitting a Green Project Reserve (GPR) business case for your proposed Advanced Treatment Project, funded through the Drinking Water State Revolving Fund (DWSRF). A provision of the 2011, DWSRF funding cycle requires that to the extent there are eligible project applications; states shall use 20% of its Drinking Water State Revolving Fund capitalization grant for green infrastructure projects. These projects are intended to address water and energy efficiency improvements or other environmentally innovative activities. The Kentucky Division of Water (KY DOW) has reviewed the GPR business case for the Advanced Treatment Project for the Fort Thomas Water Treatment Plant, Memorial Parkway Water Treatment Plant and the Taylor Mill Water Treatment Plant. Items 1.1-1.3, Items 2.1-2.4, and Item 3.1-3.10 were determined to be acceptable with a construction cost of $ 3,349,300. If the scope of the project is altered in any way to exclude the GPR eligible components, the Northern KY Water District shall submit the changes in writing to the KY DOW and receive prior approval in writing before proceeding with construction.

We look forward to working with you in finalizing your drinking water treatment project. If you have any questions regarding this correspondence, please contact me at (502) 564-3410, ext 4824.

Sincerely,

George P. Partridge Jr.

George P. Partridge Jr., P.E.
Kentucky Division of Water

Cc: NKWD – Amy Kramer, P.E.
DWSRF File

DRINKING WATER STATE REVOLVING FUND
GREEN PROJECT RESERVE
ELIGIBLE PROJECT COMPONENTS
BUSINESS CASE

Northern Kentucky Water District
Advanced Treatment Project
WX21117208

December 8, 2010

Prepared by:

Northern Kentucky Water District
2835 Crescent Springs Road
P.O. Box 18640
Erlanger, KY 41018

STATE OF KENTUCKY
Amy Kay Kramer
22412
12/9/10
LICENSED
PROFESSIONAL ENGINEER

Reviewed by:

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Lexington, KY 40503

BACKGROUND

The Northern Kentucky Water District (District) intends to install advanced treatment processes at its three water treatment plants. The advanced treatment processes being installed include granular activated carbon downstream of the conventional filters for removal of organic compounds as well as disinfection with ultraviolet (UV) light. Construction of the projects at Fort Thomas and Memorial Parkway is underway and the Taylor Mill project is in the final design review and approval stage. The construction costs for the projects are presented in Table 1 below:

Table 1
Construction Cost for
Northern Kentucky Water District
Advanced Treatment Project

Project Name	**Construction Cost**
Fort Thomas Treatment Plant (contractor bid)	$23,823,000
Memorial Parkway Treatment Plant (contractor bid)	$12,227,000
Taylor Mill Treatment Plant (engineer's estimated)	$28,000,000
Total Advanced Treatment Construction Cost	**$64,050,000**

In 2009 the District was approved for an $8 million Drinking Water State Revolving Fund Loan for the Fort Thomas Treatment Plant Advanced Treatment project and the Memorial Parkway Treatment Plant Advanced Treatment Project (WX21117208). The District is seeking to amend this loan as part of the 2011 DWSRF approval process to include the Taylor Mill Treatment Plant Advanced Treatment project. An additional $8 million is under consideration for approval by the Kentucky Infrastructure Authority Board on December 9, 2010 for the District's Advanced Treatment Project.

This document was prepared by the Northern Kentucky Water District in association with the design engineering firms CH2MHILL/HDR Engineers, who designed the improvements for Fort Thomas Treatment Plant and Memorial Parkway Treatment Plant, and Malcolm Pirnie/GRW Engineers, who designed the improvements for Taylor Mill Treatment Plant.

Questions regarding this document should be directed to the following contact person:

Ms. Amy Kramer, P.E.
Design Engineering Manager
Northern Kentucky Water District
P.O. Box 18640
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The purpose of this document is to identify components for the referenced project that may be eligible for the Green Project Reserve for the Drinking Water State Revolving Fund Loan. The components identified and described in this report include:

Category 1 – Green Infrastructure
Item 1.1 – Vegetative Roof at Fort Thomas Treatment Plant
Item 1.2 – Rain Garden at Fort Thomas Treatment Plant
Item 1.3 – Vegetative Roof at Taylor Mill Treatment Plant

Category 2 – Water Efficiency
Item 2.1 – Equalization Basin and Recycle Pumps at Fort Thomas Treatment Plant
Item 2.2 – Piping to Recycle Water to Memorial Parkway Treatment Plant Reservoir
Item 2.3 – Equalization Basin and Recycle Pumps at Taylor Mill Treatment Plant
Item 2.4 – Air Scour Blower at Fort Thomas Treatment Plant

Category 3 – Energy Efficiency
Item 3.1 – Variable Speed Drives at Fort Thomas Treatment Plant
Item 3.2 – SCADA Control System at Fort Thomas Treatment Plant
Item 3.3 – Variable Speed Drives at Memorial Parkway Treatment Plant
Item 3.4 - SCADA Control System at Memorial Parkway Treatment Plant
Item 3.5 – Variable Speed Drives at Taylor Mill Treatment Plant
Item 3.6 - SCADA Control System at Taylor Mill Treatment Plant
Item 3.7 – Site Excavation at Fort Thomas Treatment Plant
Item 3.8 – Lighting at Fort Thomas Treatment Plant
Item 3.9 – Lighting at Memorial Parkway Treatment Plant
Item 3.10 – Lighting at Taylor Mill Treatment Plant

Category 4 – Environmentally Innovative
Item 4.1 – Ultraviolet Light Disinfection at Fort Thomas Treatment Plant
Item 4.2 – Ultraviolet Light Disinfection at Memorial Parkway Treatment Plant
Item 4.3 – Granular Activated Carbon at Fort Thomas Treatment Plant
Item 4.4 – Granular Activated Carbon at Memorial Parkway Treatment Plant
Item 4.5 – Granular Activated Carbon at Taylor Mill Treatment Plant

Each of these items will be discussed individually in this document.

DESCRIPTION OF ELIGIBLE ITEMS

Category 1 – Green Infrastructure

Item 1.1 – Vegetative Roof at Fort Thomas Treatment Plant
This component of the project is eligible as a **Categorical Project** under Green Infrastructure (see 1.2-3 "Green roofs" in Part B of DWSRF GPR Specific Guidance). The pitched vegetative roof covers 14,600 of the building housing the advanced treatment processes at the Fort Thomas Treatment Plant. The roofing system consists of a waterproofing membrane and flashing, the garden roof components, and plants. The garden roof components include a root barrier to protect the membrane, a drainage course to collect any stormwater that is not retained, a water retention mat to hold 0.32 gallons per square foot, a 3" high soil retention grid to keep growing medium from moving, and 6 inches of a growing medium. The vegetation consists of established plants in trays consisting of several species of sedum. The contractor will furnish a 2-

year warranty on the entire roofing system and then the manufacturer will provide a 15-year warranty on the garden roof components (excluding plants) and a 20-year warranty on the membrane.

The United States Environmental Protection Agency report titled "Green Roofs for Stormwater Runoff Control" published February 2009 stated the a green roof can retain 50% or more of the annual precipitation. The runoff from the roof will be collected in an equalization basin that is integral with the building foundation and recycled to the raw water storage reservoirs at the treatment plant. In addition to reducing stormwater runoff, the green roof will also reduce the heat absorption during summer months and will help insulate during cold months.

Furthermore, the vegetative roof eliminated the need for a stormwater detention basin which would have been difficult and costly to construct on the site. The estimated cost for a detention pond based on the engineer's estimate for a similar structure at the Taylor Mill plant is $220,000.

The estimated cost for the vegetative roof at Fort Thomas is $278,000.

<u>Item 1.2 – Rain Garden at Fort Thomas Treatment Plant</u>
The proposed rain garden at the Fort Thomas Treatment Plant is considered a bioretention project and is eligible as a **Categorical Project** under Green Infrastructure (see 1.2-2 "Bioretention" in Part B of DWSRF GPR Specific Guidance). The planting area is approximately 5 feet wide by 80 feet long and is intended to reduce the amount of stormwater runoff from an estimated 50,000 square foot area behind the building. A total of 264 plants that are suitable for rain gardens will be placed in this area. The plants include 12 different perennials such as milkweed, butterfly weed, cardinal flower, blackeyed susan, iris, sedge, aster, and soft rush. The Wisconsin Department of Natural Resources document titled "Rain Gardens, A How-To Manual for Homeowners" indicates a rain garden retains 30% more water than a conventional patch of lawn. The rain garden will reduce the amount of stormwater that will enter the catch basin at the downstream end of the garden.

The estimated cost of the garden is $5 per square foot or $2,000.

<u>Item 1.3 – Vegetative Roof at Taylor Mill Treatment Plant</u>
This component of the project is eligible as a **Categorical Project** under Green Infrastructure (see 1.2-3 "Green roofs" in Part B of DWSRF GPR Specific Guidance). The pitched vegetative roof covers 16,000 of the building housing the advanced treatment process at the Taylor Mill Treatment Plant. The roofing system consists of a waterproofing membrane and flashing, the garden roof components, and plants. The garden roof components include a root barrier to protect the membrane, a drainage course to collect any stormwater that is not retained, a water retention mat, a soil retention grid to keep growing medium from moving, and growing medium. The vegetated roof assembly may be 4 to 8 inches deep. The established plants will include several species of sedum. The contractor will furnish a 2-year warranty on the entire roofing system and then the manufacturer will provide a 15-year warranty on the garden roof components (excluding plants) and a 20-year warranty on the membrane.

The United States Environmental Protection Agency report titled "Green Roofs for Stormwater Runoff Control" published February 2009 stated the a green roof can retain 50% or more of the annual precipitation. In addition to reducing stormwater runoff, the green roof will also reduce the heat absorption during summer months and will help insulate during cold months.

Furthermore, the vegetative roof avoided the need for a larger stormwater detention basin. The estimated additional cost to enlarge a detention pond, according to the engineer, is $5,000.

The estimated cost for the roof is $305,000.

Category 2 – Water Efficiency

Item 2.1 – Equalization Basin at Recycle Pumps at Fort Thomas Treatment Plant
This component of the project is eligible as a **Categorical Project** under Water Efficiency (see 2.2-13 "Internal plant water reuse" in Part B of DWSRF GPR Specific Guidance as well as 1.2-4 "Rainwater harvesting/cisterns). An equalization basin that is integral with the building foundation will be used to collect spent water that is used in the process plus groundwater and stormwater. If this water was not collected and recycled it would be disposed by going to sanitary sewer or storm sewer depending on the source. Recycling the water also reduces the volume of raw water that would be pumped to the reservoirs from the Ohio River Pumping Station. The process water includes water used to backwash the carbon beds (needed to remove fine carbon particles for newly installed carbon and to gently loosen the carbon bed every few weeks so it does not get too compacted) as well as the initial water sent through the carbon beds immediately following a backwash event. The equalization basin will also be used to collect slurry water used to transport new carbon from the delivery trucks to the contactors and during removal of spent carbon to the trucks. Returning the carbon fines to the raw water reservoir may be beneficial in removing compounds that form taste and odors in the water.

The equalization basin also collects groundwater from a 6" foundation drain around the perimeter of the building as well as stormwater runoff from the vegetative roof and a standing seam metal roof. A 3,200 square foot section of building is covered with a pitched metal roof. The stormwater collected from both roofs is conveyed to the equalization basin. This water may be diverted away from the equalization basin to the stormwater collection system, if maintenance activities are being performed on the roof. The basin also serves as the receiving structure for emergency overflows and pumped discharge should we need to drain the water from the wet well of the GAC pumping station.

The cost for the metal roof and small collection piping is not included in this item, but the equalization basin structure, pumping equipment, conveyance piping for recycled water, and the outfall structure at the reservoirs is included. The size of the basin is 81 feet by 70 feet with a high water level of 8 feet, so the capacity of the basin is approximately 385,000 gallons.

The estimated cost is $587,300 with a breakdown of $400,000 for the concrete structure, $50,000 for process piping and valves, $60,000 for the two 3,300 gallon per minute 70 horsepower pumps, $70,000 for 1,925 lineal feet of 24" ductile iron pipe and valves serving as the conveyance piping from the equalization tank to the outfall, and $7,300 for the concrete and rock outfall structure.

Item 2.2 – Piping to Recycle Water to Memorial Parkway Treatment Plant Reservoir
This component of the project is eligible as a **Categorical Project** under Water Efficiency (see 2.2-13 "Internal plant water reuse" in Part B of DWSRF GPR Specific Guidance). Rather than sending to sanitary sewer, the wasted process water is captured and conveyed by gravity to the raw water storage reservoirs. Recycling the water also reduces the volume of raw water that would be pumped to the reservoirs from the Ohio River Pumping Station. The wasted process water is the spent water used to backwash the carbon beds (needed to remove fine carbon particles for newly installed carbon and to gently loosen the carbon bed every few weeks so it does not get too compacted) as well as the initial water sent through the carbon beds immediately following a backwash event. Returning the carbon fines to the raw water reservoir may be beneficial in removing compounds that form taste and odors in the water.

The estimated cost for the 12" and 36" process piping, fittings, and valves needed to return the water to the reservoirs is $30,000.

Item 2.3 – Equalization Basin and Recycle Pumps at Taylor Mill Treatment Plant
This component of the project is eligible as a **Categorical Project** under Water Efficiency (see 2.2-13 "Internal plant water reuse" in Part B of DWSRF GPR Specific Guidance). Rather than sending to sanitary sewer, the wasted process water is captured and conveyed by pumping to the raw water main. Recycling the water also reduces the volume of raw water that would be pumped from the Licking River Pumping Station. The wasted process water is the spent water used to backwash the carbon vessles (needed to remove fine carbon particles for newly installed carbon and to gently loosen the carbon bed every few weeks so it does not get too compacted) as well as the initial water sent through the carbon immediately following a backwash event. Returning the carbon fines to the raw water may be beneficial in removing compounds that form taste and odors in the water.

The equalization basin at the Taylor Mill plant has an approximate capacity of 45,000 gallons. The process wastewater is collected from backwashing and truck draining activities and vessel-to-waste upon initial startup and returned into the raw water line at the head of the treatment process. Pumping is accomplished by using two submersible pumps with one being a standby pump and one being a duty pump. Each pump has a capacity of 300 gpm at 33 feet.

The estimated cost for the tank, pump, piping, and fittings is $175,000 with a breakdown of $15,000 for piping, $20,000 for pumps, and $140,000.

Item 2.4 – Air Scour Blower at Fort Thomas Treatment Plant
This component of the project is eligible as a **Categorical Project** under Water Efficiency (see 2.2-6 "Programs reasonably expected to result in a reduction in demand to alleviate the need for additional investment" in Part B of DWSRF GPR Specific Guidance). A blower system was added as part of the Fort Thomas Treatment Plant project to aid in the backwashing operations. It is believed that the blower will reduce the amount of water needed to backwash filters by approximately 50%. The water used for backwash is not yet considered potable, but it is pumped and treated by a significant part of process. The equalization basin can hold spent water from almost 30 minutes of backwashing. Site visits to utilities without backwashing capability indicated much longer times may be needed to remove carbon fines. The size of the tank was not enlarged to accommodate a higher volume, which saved consider construction cost. Additionally, the submersible pumps in the equalization tank will not need to pump as much backwash water to the reservoirs. This reduced pumping is a savings in energy cost. The blower's design capacity is sized properly at 1,760 scfm and is not to exceed the motor horsepower at a 1.15 service factor as suggested in Appendix D of the United States Environmental Protection Agency report "Ensuring a Sustainable Future: An Energy Management Guidebook for Wastewater and Water Utilities". The 200 HP motor must meet energy efficiency levels as required by National Electrical Manufacturers Association (NEMA) Table 12-12. This equates to a nominal motor efficiency rating of 95%.

The estimated cost of the blower is $152,000.

Category 3 – Energy Efficiency

Item 3.1 – Adjustable Speed Drives at Fort Thomas Treatment Plant
This component of the project is eligible as a **Categorical Project** under Energy Efficiency (see 3.2-2 "Energy management planning and practices" in Part B of DWSRF GPR Specific Guidance). The three pumps for feeding the carbon contactors at Fort Thomas are vertical turbine pumps with a rated capacity of 15,300 gpm at 43.7 feet of head. The motors are 250 horsepower with a service factor of 1.15 and a nominal efficiency rating of 95%. The pumps are driven by low-voltage adjustable speed drives (ASDs). The ASDs will allow the pumps to continuously operate at their design point, creating an advantage in hydraulic efficiency as compared to the operation of a pump driven by a constant speed motor. The minimum hydraulic efficiency of the overall pump and motor with the ASD is specified to be 86%, whereas the variable flow conditions with a constant speed pump may lower the efficiency closer to 70%.

The estimated cost for the pumps, motors and ASDs is $256,000.

Item 3.2 – SCADA Control System at Fort Thomas Treatment Plant
This component of the project is eligible as a **Categorical Project** under Energy Efficiency (see 3.2-2 "Energy management planning and practices" in Part B of DWSRF GPR Specific Guidance). The process control will optimize plant operations leading to more efficient use of energy.

The estimated cost for SCADA is $25,500.

Item 3.3 – Adjustable Speed Drives at Memorial Parkway Treatment Plant

This component of the project is eligible as a **Categorical Project** under Energy Efficiency (see 3.2-2 "Energy management planning and practices" in Part B of DWSRF GPR Specific Guidance). The four pumps for feeding the carbon contactors at Memorial Parkway are vertical turbine pumps with two having a rated capacity of 7,000 gpm at 42 feet of head and two 3,500 gpm at 42 feet of head. The motors are 125 horsepower for the larger pumps and 60 horsepower for the smaller pumps, with a service factor of 1.15 and a nominal efficiency rating of 95%. The pumps are driven by low-voltage adjustable speed drives (ASDs). The ASDs will allow the pumps to continuously operate at their design point, creating an advantage in hydraulic efficiency as compared to the operation of a pump driven by a constant speed motor. The minimum hydraulic efficiency of the overall pump and motor with the ASD is specified to be 80%, whereas the variable flow conditions with a constant speed pump may lower the efficiency closer to 70%.

The estimated cost for the pumps, motors and ASDs is $110,000.

Item 3.4 - SCADA Control System at Memorial Parkway Treatment Plant

This component of the project is eligible as a **Categorical Project** under Energy Efficiency (see 3.2-2 "Energy management planning and practices" in Part B of DWSRF GPR Specific Guidance). The process control will optimize plant operations leading to more efficient use of energy.

The estimated cost for SCADA is $31,500.

Item 3.5 – Adjustable Speed Drives at Taylor Mill Treatment Plant

This component of the project is eligible as a **Categorical Project** under Energy Efficiency (see 3.2-2 "Energy management planning and practices" in Part B of DWSRF GPR Specific Guidance). The three pumps for feeding the carbon vessels at Taylor Mill are vertical turbine pumps with a rated capacity of 4,166 gpm at 70 feet of head. The motors are 125 horsepower with a service factor of 1.15 and a nominal efficiency rating of 84%. The pumps are driven by low-voltage adjustable speed drives (ASDs). The ASDs will allow the pumps to continuously operate at their design point, creating an advantage in hydraulic efficiency as compared to the operation of a pump driven by a constant speed motor. The minimum hydraulic efficiency of the overall pump and motor with the ASD is specified to be 80%, whereas the variable flow conditions with a constant speed pump may lower the efficiency closer to 70%.

The estimated cost for the pumps, motors and ASDs is $465,000.

Item 3.6 - SCADA Control System at Taylor Mill Treatment Plant

This component of the project is eligible as a **Categorical Project** under Energy Efficiency (see 3.2-2 "Energy management planning and practices" in Part B of DWSRF GPR Specific Guidance). The process control will optimize plant operations leading to more efficient use of energy. In addition to greater control over pumping to the GAC pressure vessels, the preliminary treatment process will use SCADA to feed the proper amount of chemicals and to automate the removal of settled solids from the basins.

The estimated cost for SCADA is $50,000.

Item 3.7 – Site Excavation at Fort Thomas Treatment Plant
This component of the project is eligible as a **Categorical Project** under Energy Efficiency (see 3.2-2 "Energy management planning and practices" in Part B of DWSRF GPR Specific Guidance). The building at Fort Thomas will largely be constructed in a hillside, which will help to reduce heat absorption during summer months and will provide natural insulation during cold months. Roughly 37 feet of the building depth is below ground level. The square footage of the building footprint is 20,000 square feet.

The cost to excavate the structure is $17.50 a cubic yard or roughly $500,000 for the building.

Item 3.8 – Lighting at Fort Thomas Treatment Plant
This component of the project is eligible as a **Categorical Project** under Energy Efficiency (see 3.2-2 "Energy management planning and practices" in Part B of DWSRF GPR Specific Guidance). The lamps and ballasts are specified to be energy efficient and have motion sensors to automatically control the lighting based on occupancy.

The estimated cost of the lighting is $150,000.

Item 3.9 – Lighting at Memorial Parkway Treatment Plant
This component of the project is eligible as a **Categorical Project** under Energy Efficiency (see 3.2-2 "Energy management planning and practices" in Part B of DWSRF GPR Specific Guidance). The lamps and ballasts are specified to be energy efficient and have motion sensors to automatically control the lighting based on occupancy.

The estimated cost of the lighting is $100,000.

Item 3.10 – Lighting at Taylor Mill Treatment Plant
This component of the project is eligible as a **Categorical Project** under Energy Efficiency (see 3.2-2 "Energy management planning and practices" in Part B of DWSRF GPR Specific Guidance). The lamps and ballasts are specified to be energy efficient and have motion sensors to automatically control the lighting based on occupancy. Existing lighting fixtures on the third floor of the filter building that were installed in the 1950s are being replaced with energy efficient fixtures as well.

The estimated cost of the lighting is $132,000.

Category 4 – Environmentally Innovative

Item 4.1 – Ultraviolet Light Disinfection at Fort Thomas Treatment Plant
This component of the project falls under the Environmentally Innovative Category (see 4.5 "Application of innovative treatment technologies or systems that improve environmental conditions and eliminate the use of chemicals in water treatment" in Part B of DWSRF GPR Specific Guidance). This process will enhance the level of disinfection of the water without the need to use more chlorine than presently used or to add a

different chemical disinfectant. The process uses UV light for disinfection, which is more effective than chlorine for *Cryptosporidium*.

The cost of the UV equipment is $712,000.

Item 4.2 – Ultraviolet Light Disinfection at Memorial Parkway Treatment Plant
This component of the project falls under the Environmentally Innovative Category (see 4.5 "Application of innovative treatment technologies or systems that improve environmental conditions and eliminate the use of chemicals in water treatment" in Part B of DWSRF GPR Specific Guidance). This process will enhance the level of disinfection of the water without the need for any additional chemicals such as chlorine. The process uses UV light for disinfection, which is more effective than chlorine for *Cryptosporidium*.

The cost of the UV equipment is $477,000.

Item 4.3 – Granular Activated Carbon at Fort Thomas Treatment Plant
This component of the project falls under the Environmentally Innovative Category (see 4.5 "Application of innovative treatment technologies or systems that improve environmental conditions and eliminate the use of chemicals in water treatment" in Part B of DWSRF GPR Specific Guidance). This process will remove organic compounds that are contained in the raw water withdrawn from the Ohio River. These compounds may be naturally occurring or may be added through surface water runoff during storms (non-point sources) or from direct discharges from wastewater or industrial facilities.

The estimated cost for the granular activated carbon media is $3,641,100. This is just the cost of the media and does not include the concrete basins, support underdrains, or piping associated with the contactors.

Item 4.4 – Granular Activated Carbon at Memorial Parkway Treatment Plant
This component of the project falls under the Environmentally Innovative Category (see 4.5 "Application of innovative treatment technologies or systems that improve environmental conditions and eliminate the use of chemicals in water treatment" in Part B of DWSRF GPR Specific Guidance). This process will remove organic compounds that are contained in the raw water withdrawn from the Ohio River. These compounds may be naturally occurring or may be added through surface water runoff during storms (non-point sources) or from direct discharges from wastewater or industrial facilities.

The estimated cost for the granular activated carbon media is $806,600. This is just the cost of the media and does not include the concrete basins, support underdrains, or piping associated with the contactors.

Item 4.5 – Granular Activated Carbon at Taylor Mill Treatment Plant
This component of the project falls under the Environmentally Innovative Category (see 4.5 "Application of innovative treatment technologies or systems that improve environmental conditions and eliminate the use of chemicals in water treatment" in Part B of DWSRF GPR Specific Guidance). This process will remove organic compounds that are contained in the raw water withdrawn from the Licking River. These compounds

may be naturally occurring or may be added through surface water runoff during storms (non-point sources) or from direct discharges from wastewater or industrial facilities.

The estimated cost for the granular activated carbon media is $784,000. This is just the cost of the media and does not include the steel pressure vessels or any ancillary equipment or piping associated with the process.

RESULTS

A number of unit costs were determined to estimate the savings from green, energy efficiency, and water efficiency measures.

- The current rate for wastewater is $6.76 per 1,000 gallons.
- The current wholesale customer rate for water is $2.97 for 1,000 gallons and will be used for determining water efficiency costs.
- The power costs for both Fort Thomas and Memorial Parkway Treatment Plants are based on a Distribution Time-of-Day rate follows:

  Energy Charge per kWh, FTTP and MPTP
    - Summer On Peak $0.054418
    - Winter On Peak $0.052118
    - Off Peak $0.046118

- The power cost at the Taylor Mill Treatment Plant is based on a Transmission Time-of-Day rate follows:

  Energy Charge per kWh, TMTP $0.052571

- For simplicity an average energy cost of $0.05 per kWh will be used for calculating the estimated savings.
- For the water recycling projects leading to enhanced water efficiency, the estimated cost savings for not having to pump raw water into reservoirs at each plant approximately $0.07 per 1,000 gallons.

1.0 Green Infrastructure Projects

Item 1.1 – Vegetative Roof at Fort Thomas Treatment Plant
The savings in green roofs is realized from both heating and cooling energy savings and the reduction of stormwater that needs to be handled and treated at the wastewater treatment plant if not controlled. The heating required for the GAC Operating Floor, Second Floor Restroom, Stairwell 1, and Stairwell 2 will benefit from the vegetative roof. It is estimated that heating requirements will be reduced by about 10% because of the roof.

EUH-15, 16, 17, 18, 19 serving GAC Operating Floor = 15 kW each

EWH-1 serving Stairwell 2 = 5 kW
EWH-2 serving Stairwell 1 = 5 kW
EWH-3 serving the Second Floor Restroom = 2 kW
Total heating requirements = 87 kW

87 kW x 12 hrs/day x 30 days/mo x 8 mos x $0.05/kWh x 0.10 = $1,253

The estimated annual power savings is $1,250.

It is assumed that the green roof reduces the stormwater runoff by 50% a year. The total estimated precipitation is about 42" a year for the Cincinnati, Ohio and the surrounding area according to the U.S. Climate Data. The size of the green roof at Fort Thomas is 14,600 square feet so a total of 382,200 gallons of precipitation would fall on the roof each year. The green roof will retain about half or 191,100 gallons of stormwater a year.

Other benefits of a green roof include an improvement in air quality by lowering greenhouse gases and airborne particulates, reduced building noise, extended roof life, and it will attract desirable wildlife such as song birds and butterflies.

The estimated annual savings by not having to treat the stormwater retained by the green roof, assuming the stormwater would eventually enter the sanitary sewer system and the District billed for this amount, is $1,290.

<u>Item 1.2 – Rain Garden at Fort Thomas Treatment Plant</u>
The estimated annual stormwater falling on the 50,000 square foot area behind the building is 1,308,901 gallons. For simplicity, it is assumed that 50% of the annual precipitation is retained by a conventional grass lawn (this assumption was not scientifically verified). If a rain garden retains another 30% more, then an additional 196,335 gallons a year is retained by the garden.

The estimated annual savings by not having to treat the stormwater retained by the rain garden, assuming the stormwater would eventually enter the sanitary sewer system and the District billed for this amount, is about $1,325.

<u>Item 1.3 – Vegetative Roof at Taylor Mill Treatment Plant</u>
The heating required for the GAC Building will benefit from the vegetative roof. It is estimated that heating requirements will be reduced by about 10% because of the roof.

ACCU-1 serving the admin. and lab area = 9.4 kW
ACCU-2 serving the admin. And lab area = 2.5 kW
DDH-1 (NG Space Only) serving the GAC portion of the building = 179 kW
DDH-1 (Electrical Only) serving the GAC portion of the building = 33 kW
PACU-1 (Heat) serving electrical room on landing = 8.3 kw
FCU-1A serving the lab = 0.10 kW
FCU-1B serving the administrative room = 0.10 kW
FCU-1C serving the corridor = 0.12 kW
FCU-1D serving the corridor = 0.12 kW

FCU-2 serving the electrical room = 0.19 kW
EWH-1 serving the Restroom = 3 kW
EWH-2 serving the Restroom = 3 kW
EUH-6 serving the residuals pump room = 3.6 kW

Total heating requirements (non-natural gas units) = 63.33 kW

63.33 kW x 12 hrs/day x 30 days/mo x 8 mos x $0.05/kWh x 0.10 = $912

Total heating requirements (DDH-1 natural gas unit, convert to equivalent natural gas units: $1.25 / 100,000 Btu x 3412 Btu/Hr / KW = $0.043 / kWH) = 179 kW

179 kW x 12 hrs/day x 30 days/mo x 8 mos x $0.043/kWh x 0.10 = $2,217

The estimated annual power savings is $3,129.

It is assumed that the green roof reduces the stormwater runoff by 50% a year. The total estimated precipitation is about 42" a year for the Cincinnati, Ohio and the surrounding area according to the U.S. Climate Data. The size of the green roof at Taylor Mill is 16,000 square feet, so a total of 418,800 gallons of precipitation would fall on the roof each year. The green roof will retain about half or 209,400 gallons of stormwater a year.

The estimated annual savings by not having to treat the stormwater retained by the green roof, assuming the stormwater would eventually enter the sanitary sewer system and the District billed for this amount, is $1,415.

Category 2 – Water Efficiency

Item 2.1 – Equalization Basin and Recycle Pumps at Fort Thomas Treatment Plant
The stormwater not retained by the green roof will be sent to the equalization basin and sent to the reservoirs and combined with the raw water entering the treatment plant. The half of the precipitation not retained by the green roof is about 191,100 gallons of stormwater a year. The volume of water collected from the metal roof runoff in a year is approximately 83,800 gallons.

The process water that is collected from the backwash of contactors and carbon changeouts during a year totals 40,950,400 gallons. This total breaks down to 7,603,000 for backwashing each of the eight 880 square foot contactors at a rate of 6 gallons a minute for 120 minutes once a year following carbon change out plus backwashing each contactor once a month for 5 minutes at 6 gallons a minute; plus 50,000 of slurry water to remove GAC from the contactor and place it in a truck and to move it from the delivery truck into the contactor, each contactor once a year for a total of 400,000 gallons of slurry water annually. Additionally, the contactor-to-waste cycle for 60 minutes at 6 gpm per square foot following each of the 104 backwash cycles a year generates 32,947,200 gallons.

The total amount of all stormwater and process water collected in the equalization basin and returned to the reservoirs is 41,034,200 gallons. The cost to pump this water from the river would be $2,870 a year. The estimated annual savings by not having to treat the process water and stormwater recycled to the reservoirs through a wastewater treatment plant is $277,390.

<u>Item 2.2 – Piping to Recycle Water to Memorial Parkway Treatment Plant Reservoir</u>
This plant will recycle a total of 2,021,760 for backwashing each of the three 624 square foot contactors at a rate of 6 gallons a minute per square foot for 120 minutes once a year following carbon change out and to backwash each contactor once a month for 5 minutes at 6 gallons a minute; plus 30,000 of slurry water to remove GAC from the contactor and place it in a truck and to move it from the delivery truck into the contactor, each contactor once a year for a total of 90,000 gallons of slurry water annually. Additionally a contactor-to-waste cycle recycles water to the reservoirs following each backwash event. The contactor-to-waste process assumes that each contactor treats 6 gpm for 60 minutes for a total of 39 times a year generating 8,760,960 gallons. The total volume process water that is collected from the backwash of contactors, carbon changeouts, and contactor-to-waste during a year totals 10,872,720 gallons.

The cost to pump this water from the river would be about $760 a year.

The estimated annual savings by not having to treat the process water recycled to the reservoirs through a wastewater treatment plant is $73,500.

<u>Item 2.3 – Equalization Basin and Recycle Pumps at Taylor Mill Treatment Plant</u>
The estimated volume for backwashing the vessels is 1,000 gpm for 30 minutes once a year for each of the 14 vessels once a month for 5 minutes is 1,260,000 gallons a year; it is estimated that 60 minutes of vessel-to-waste at about 500 gpm following each backwash generates another 5,460,000 gallons a year; the truck water to move carbon will use approximately 20,000 gallons a vessel per changeout, each vessel once a year, for a total of 280,000 gallons of slurry water. The total volume put in the equalization tank and recycled to the raw water main in a year is 7,000,000.

The cost to pump this water from the river would be about $500 a year.

The estimated annual savings by not having to treat the process water recycled to the plant through a wastewater treatment plant is $47,320.

<u>Item 2.4 – Air Scour Blower at Fort Thomas Treatment Plant</u>
It is estimated that at least twice the amount of water would be needed annually to backwash the carbon contactors following a change out procedure. This would total 5,068,800 for backwashing each of the eight 880 square foot contactors at a rate of 6 gallons a minute for an additional 120 minutes once a year. The cost of water for this volume is $15,050 a year using the cost to treat water that would be used for backwash is $2.97 per 1,000 gallons. The estimated energy savings by not running the backwash pump an additional 16 hours a year is $125.

Category 3 – Energy Efficiency

Item 3.1 – Adjustable Speed Drives at Fort Thomas Treatment Plant
The average flow through the plant is 13,900 gpm. It is assumed that on average one pump will run continuously 365 days a year. The pump with the ASDs will produce annual energy consumption and costs as follows:

250 HP/0.86 x 0.7457 kW per HP x 365 days x 24 hrs = 1,898,933 kWh a year

A pump without an ASD would produce the following estimated cost:

250 HP/0.70 x 0.7457 kW per HP x 365 days x 24 hrs = 2,332,976 kWh a year

The difference is 434,042 kWh a year or $21,700.

Item 3.2 – SCADA Control System at Fort Thomas Treatment Plant
It is estimated that SCADA control will improve energy use approximately 10 to 15 percent, although an industry benchmark was not located. This amount of savings is in-line with reports from optimization software companies that perform similar functions.

GAC Pump = 250 HP/0.86 x 0.7457 kW/HP x 365 days x 24 hrs x $0.05/kWh = $94,946.
GAC BW Pump = 200 HP/0.88 x 0.7457 kW/HP x 24 hrs x $0.05/kWh = $203
Filter BW Pump =200 HP/0.88 x 0.7547 kW/HP x 500 hrs x $0.05/kWh = $4,288

The total cost for power for the equipment listed above is about $99,500 a year. It is estimated that approximately $10,000 a year is saved by having SCADA control.

Item 3.3 – Adjustable Speed Drives at Memorial Parkway Treatment Plant
The average flow through the plant is 2,500 gpm. It is assumed that on average one pump will run continuously 260 days a year. The pump with the ASDs will produce annual energy consumption and costs as follows:

125 HP/0.80 x 0.7457 kW per HP x 260 days x 24 hrs = 727,057 kWh a year

A pump without an ASD would produce the following estimated cost:

125 HP/0.70 x 0.7457 kW per HP x 260 days x 24 hrs = 830,922 kWh a year

The difference is 103,865 kWh a year or $5,190.

Item 3.4 - SCADA Control System at Memorial Parkway Treatment Plant
It is estimated that SCADA control will improve energy use approximately 10 to 15 percent, although an industry benchmark was not located. This amount of savings is in-line with reports from optimization software companies that perform similar functions.

GAC Pump = 125 HP/0.80 x 0.7457 kW/HP x 260 days x 24 hrs x $0.05/kWh = $36,352

It is estimated that approximately $4,000 a year is saved by having SCADA control.

Item 3.5 – Adjustable Speed Drives at Taylor Mill Treatment Plant
The average flow through the plant is 5,200 gpm. It is assumed that one 4,100 gpm pump will run continuously 310 days a year and one pump will run 152 days a day for an equivalent of 462 days. The pump with the ASDs will produce annual energy consumption and costs as follows:

125 HP/0.80 x 0.7457 kW per HP x 462 days x 24 hrs = 1,291,925 kWh a year

A pump without an ASD would produce the following estimated cost:

125 HP/0.70 x 0.7457 kW per HP x 462 days x 24 hrs = 1,476,486 kWh a year

The difference is 184,560 kWh a year or $9,230.

Item 3.6 - SCADA Control System at Taylor Mill Treatment Plant
It is estimated that SCADA control will improve energy use approximately 10 to 15 percent, although an industry benchmark was not located. This amount of savings is in-line with reports from optimization software companies that perform similar functions.

GAC Pump = 125 HP/0.80 x 0.7457 kW/HP x 462 dys x 24 hrs x $0.05/kWh = $64,596
GAC BW Pump = 15 HP/0.88 x 0.7457 kW/HP x 21 hrs x $0.05/kWh = $13

The total cost for the equipment having the bulk of the energy consumption is $64,609 a year. It is estimated that approximately $6,500 a year is saved by having SCADA.

Item 3.7 – Site Excavation at Fort Thomas Treatment Plant
The energy savings for burying the building in the hillside are estimated to be about the same as for a green roof or 10%. The building needed to be constructed to this depth to provide the optimal hydraulic gradient for minimizing pumping head for lifting water into the GAC contactors and for allowing gravity flow to the clearwells. The energy savings realized by insulating the building using the ground is an added benefit to keeping the pumping costs lower. The heating required for the Lower Level, First Floor, Stairwell 1, and Stairwell 2 will benefit from the below-grade structure.

EUH-8 serving lower pump room = 7.5 kW
EUH-9 serving lower pump room = 10 kW
EUH-11,12,13,14 serving pipe gallery = 7.5 kW each
EUH 21, 22 serving electrical and maintenance = 5.0 kW each
EWH-1 serving Stairwell 2 = 5 kW
EWH-2 serving Stairwell 1 = 5 kW
EWH-4 serving the Basement Restroom = 2 kW
EWH-5 serving the First Floor Restroom = 2 kW
Total heating requirements = 71.5 kW

71.5 kW x 12 hrs/day x 30 days/mo x 8 mos x $0.05/kWh x 0.10 = $1,030

The estimated annual power savings is $1,030.

Item 3.8 – Lighting at Fort Thomas Treatment Plant
It is estimated that approximately 105,000 kWh a year will be needed to power the lights added by this project. This equates to $5,250. It is assumed that energy efficient fixtures saving about 20% a year over less efficient fixtures. This equates to a savings of $1,050 a year.

Item 3.9 – Lighting at Memorial Parkway Treatment Plant
It is estimated that approximately 60,000 kWh a year will be needed to power the lights added by this project. This equates to $3,000. It is assumed that energy efficient fixtures saving about 10% a year over less efficient fixtures. This equates to a savings of $600 a year.

Item 3.10 – Lighting at Taylor Mill Treatment Plant
It is estimated that approximately 175,000 kWh a year will be needed to power the lights added by this project. This equates to $8,750. There are 30 existing fixtures using 100 watts each on the third floor that are being replaced with 21 fixtures using 60 watts. In this case the new fixtures are 40% more efficient than the old ones. It is assumed that energy efficient fixtures saving about 20% a year over less efficient new fixtures. The total savings equates to about $1,750 a year. For projects leading to efficiency, the estimated annual cost savings for each project is summarized in Table 2 below.

Table 2
Categories 1 – 3 for Green Infrastructure, Energy Efficiency, and Water Efficiency

Item Description	Construction Cost	Annual Units Saved	Cost per Unit	Total Annual Cost Savings	Payback, Years
FTTP Veg Roof	$278,000	25,000 kWh	$0.05 per kWh	$1,250	23
		136,500 gallons	$6.76 for 1,000 gallons	$1,290	
		Eliminated detention pond construction $200,000			
FTTP Garden	$2,000	196,335 gallons	$6.76 for 1,000 gallons	$1,325	1
TMTP Veg Roof	$305,000	69,800 kWh	$0.05 per kWh	$3,129	66
		209,400 gallons	$6.76 for 1,000 gallons	$1415	
		Avoided larger detention pond cost $5,000			
FTTP Recycle	$587,300	41,034,200 gallons	$0.07 for 1,000 gallons	$2,870	2
			$6.76 for 1,000 gallons	$277,390	
MPTP Recycle	$30,000	10,872,720 gallons	$0.07 for 1,000 gallons	$760	0
			$6.76 for 1,000 gallons	$73,500	
TMTP Recycle	$175,000	7,000,000 gallons	$0.07 for 1,000 gallons	$500	4
			$6.76 for 1,000 gallons	$47,320	
FTTP Air Scour	$152,000	5,068,800 gallons	$2.97 for 1,000 gallons	$15,050	10
FTTP ASDs	$256,000	434,042 kWh	$0.05 per kWh	$21,700	12
FTTP SCADA	$25,500	200,000 kWh	$0.05 per kWh	$10,000	3
MPTP ASDs	$110,000	103,865 kWh	$0.05 per kWh	$5,190	21
MPTP SCADA	$31,500	80,000 kWh	$0.05 per kWh	$4,000	8
TMTP ASDs	$465,000	184,560 kWh	$0.05 per kWh	$9,230	50
TMTP SCADA	$55,000	130,000 kWh	$0.05 per kWh	$6,500	9
FTTP Excavation	$500,000	20,592 kWh	$0.05 per kWh	$1,030	485
FTTP Lighting	$150,000	105,000 kWh	$0.05 per kWh	$1,050	143
MPTP Lighting	$100,000	60,000 kWh	$0.05 per kWh	$600	167
TMTP Lighting	$132,000	178,000 kWh	$0.05 per kWh	$1,780	74
TOTAL	**$3,354,300**	**1,590,859 kWh and 64,517,955 gallons**		**$486,879 annual plus $205,000 for construction**	

Category 4 – Environmentally Innovative

Item 4.1 – Ultraviolet Light Disinfection at Fort Thomas Treatment Plant, and
Item 4.2 – Ultraviolet Light Disinfection at Memorial Parkway Treatment Plant
The process uses UV light for disinfection, which is more effective than chlorine for inactivation of Cryptosporidium. The Cryptosporidium oocyst is known to resist treatment with chlorine, so the District would need to consider another process such as membrane filtration to achieve control of this microbe to a level that is comparable with UV.

Treatment with UV does not introduce any chemicals into the water and has not been found to produce undesirable byproducts associated with other disinfectants at the low dosage level being proposed at the 3 plants. As summarized in the attached article from American Water Works Association Journal titled "Treatment Alternatives for Compliance with Stage 2 d/DBPR: An Economic Update," byproducts are formed through the use of other disinfectants such as chloramines, chlorine dioxide, and ozone. Each of these processes adds chemicals and/or disinfection byproducts to the water and membranes are associated with much higher construction and operating costs than UV.

Along with its effectiveness for inactivating bacteria and viruses commonly found in the raw water source, the UV system is designed to provide 2.5 log inactivation of Cryptosporidium and Giardia by delivering a dose of 8.5 mJ/cm^2 in accordance with the EPA UV Disinfection Guidance Manual. This will enable the District to apply for additional disinfection credit for the new treatment process. Because UV does not provide a residual, chlorine will continue to be applied to maintain microbial control in the distribution system.

Item 4.3 – Granular Activated Carbon at Fort Thomas Treatment Plant,
Item 4.4 – Granular Activated Carbon at Memorial Parkway Treatment Plant, and
Item 4.5 – Granular Activated Carbon at Taylor Mill Treatment Plant
The GAC process will remove organic compounds that are contained in the raw water withdrawn from the Ohio River and the Licking River. These compounds may be naturally occurring or may be added through surface water runoff during storms (non-point sources) or from direct discharges from wastewater or industrial facilities. Currently it is not considered economically feasible to treat wastewater and stormwater runoff to drinking water standards to remove these compounds prior to entering the source water.

When combined with chlorine, the naturally occurring organic compounds form disinfection byproducts (DBPs). The District selected granular activated carbon (GAC) over changing to an alternative disinfectant such as chloramines, chlorine dioxide, or ozone. The District's reason for selecting GAC over alternative disinfectants mirrors the rationale presented in the attached article from the American Water Works Association Journal titled "Treatment Alternatives for Compliance with Stage 2 d/DBPR: An Economic Update." The article states that switching disinfectants to comply with the regulations is unlikely to be an effective long-term solution. The article specifically says "This is because most alternative disinfectants have negative side effects, including the formation of emerging byproducts that are likely to be regulated in the future.

Technologies that target the removal of compounds that serve as precursors for the formation of DBPs can offer the best potential for overall water quality improvement." Along with enabling the District to meet the Stage 2 regulation for DPBs, carbon is effective for removing many endocrine disrupting and pharmaceutical chemicals. These products will be trapped in the carbon particle and will be destroyed when the GAC is thermally reactivated, thereby keeping these compounds from being returned to a surface water source.

The GAC process was found to have the lowest construction and operating cost as compared to other organic removal technologies employing membranes. Although membranes are highly effective at removing the organics that form DBPs, the process would require the District to have acid on-site to clean the membranes and it produces a high volume of waste stream that must be disposed. The District experienced a high rate of fouling when membranes were tested on a pilot-scale.

The construction cost for the Category 4 Environmentally Innovative projects are summarized in Table 3.

Table 3
Environmentally Innovative Projects
Category 4

Item Description	Construction Cost
FTTP UV	$712,000
MPTP UV	$477,000
FTTP GAC	$3,641,100
MPTP GAC	$806,600
TMTP GAC	$784,000
Total	**$6,420,700**

SUMMARY AND CONCLUSIONS

A summary of the construction cost for each project category is presented in Table 4. Projects leading to directly estimated energy and water efficiency have a construction cost of $6,654,300 and an annual savings of $486,879. Additionally, the two vegetative roofs saved $205,000 in construction cost by not having to build additional detention basin storage for stormwater. The environmentally innovate projects total $6,420,700 in construction.

Of the total construction cost of $64,050,000 for the Advanced Treatment Project, consisting of improvements at the Fort Thomas Treatment Plant, the Memorial Parkway Treatment Plant, and Taylor Mill Treatment Plant, documentation for $9,775,000 is provided for consideration for the Green Project Reserve.

Table 4 Summary of Green Project Reserve Components For Advanced Treatment Project			
Category	**Construction Cost**	**Eliminated Construction Cost**	**Annual Savings**
1 – Green Infrastructure	$585,000	$205,000	$8,409
2 – Water Efficiency	$944,000	NA	$417,390
3 – Energy Efficiency	$1,825,000	NA	$61,080
4 – Environmentally Innovative	$6,420,700	NA	NA
Total	**$9,775,000**	**$205,000**	**$486,879**

ALAN J. ROY

Treatment alternatives for compliance with the Stage 2 D/DBPR: An economic update

TO HELP UTILITIES PREPARE FOR COMPLIANCE WITH STAGE 2 OF THE DISINFECTANTS/DISINFECTION BY-PRODUCTS RULE, THIS ARTICLE UPDATES THE DECEMBER 2005 REPORT FROM THE US ENVIRONMENTAL PROTECTION AGENCY ON DISINFECTION BY-PRODUCT CONTROL TECHNOLOGIES AND THEIR ASSOCIATED COSTS.

Chlorine disinfection is a long-used and highly effective means of preventing waterborne disease. However, chlorine reactions with natural organic matter (NOM) have created by-products, namely trihalomethanes (THMs) and haloacetic acids (HAAs), that also pose health risks. The US Environmental Protection Agency (USEPA) has implemented water quality standards to address these problems and to ensure the safety of the nation's drinking water.

Water utilities across the United States will soon face difficult choices as they formulate plans to comply with the requirements of the Stage 2 Disinfectants/Disinfection Byproducts Rule (D/DBPR) while working to continue controlling capital and operating costs. In December 2005 USEPA published a report on the technologies that can be used to control DBPs and their associated costs (USEPA, 2005). Since that time, a number of technologies have emerged as popular choices to achieve the Stage 2 treatment requirements. The costs associated with these technologies must also undergo significant adjustment in order to reflect current economic conditions and supply costs.

Although removal of DBPs from treated water may be economically feasible in some cases, in others prevention of DBP formation by changing the disinfectant or removing NOM would be more cost-effective. The use of alternative disinfectants is often considered an easily implemented and inexpensive means of reducing THMs and HAAs. There are, however, additional concerns with the use of alternative disinfectants, primarily the creation of other by-products that may pose their own health risks and ultimately prove to exhibit greater toxicity than THMs and HAAs—the "traditional" DBPs. A combination of treatment alternatives may be needed to produce the desired water quality.

Several treatment technologies are capable of achieving the desired treatment efficiency, often with ancillary benefits. The decision on which one or combination of these best suits a specific water utility often involves factors other than the cost of the technology.

This article reviews the popular treatment technologies used to limit production of DBPs in drinking water and updates their associated treatment costs, first published in 2005 by the USEPA. Consideration is also given to how the different technologies may be incorporated into larger treatment goals for future expansion and improved water quality.

CRITICAL QUESTIONS NEED TO BE ASKED

Before a technology assessment is done, it is often useful to conduct a detailed review of water quality parameters (both organic and inorganic), making sure to include changes that occur over the course of each year. Consideration must also be given to the additional treatment requirements of the Long Term 2 Enhanced Surface Water Treatment Rule and goals such as elimination of tastes and odors, inactivation of *Giardia* and *Cryptosporidium*, or removal of endocrine disrupting chemicals (EDCs).

Some questions commonly addressed before treatment technologies are assessed include:

- What is the available space for capital equipment?
- Is there any potential for integration with existing treatment?
- What is the potential for future expansion both in flow capacity and in scope of treatment?
- What are the local disposal options for process wastes?
- Is there a need for treatment redundancy?
- What amount and quality of operator attention can be provided to oversee the treatment?
- What needs are there for chemical storage?
- What safety considerations must be addressed in implementing a particular treatment technology?
- What are the monitoring requirements for the treatment technology and for compliance reporting?
- What permitting requirements must be satisfied in implementing a new treatment technology?

Among the precursor technologies examined, the data suggest that activated carbon continues to be the most cost-effective method.

After these considerations have been assessed and prioritized, a short list of technologies can be selected for further review and/or pilot-testing. Then a list of prospective vendors can be developed.

ALTERNATIVE DISINFECTANTS ALSO HAVE DISADVANTAGES

Some of the alternative disinfectants used in place of or in combination with traditional disinfectants include monochloramine, chlorine dioxide, ozone, and ultraviolet (UV) light. The advantages and disadvantages of using these disinfectants are described in the following sections. Other less common disinfectants that may be considered in some applications include potassium permanganate, hydrogen peroxide, bromine, and iodine.

Monochloramine. Ammonia can be added to standard free chlorine disinfection processes to produce monochloramine, which has a much lower oxidation potential with NOM and exhibits a decreased potential to produce DBPs commonly found during free chlorine addition.

Advantages. Minimized production of THMs or HAAs; maintains a residual in the distribution system.

Disadvantages. Potential to form nitrosamines (*N*-nitrosodimethylamine; Choi & Valentine, 2002; Najm & Trussell, 2001); potential to form cyanogen chloride (Weinberg et al, 2002); can produce higher concentrations of iodated byproducts than chlorine disinfection (Krasner et al, 2006); not as strong a disinfectant for microbes other than bacteria; more complicated to produce than other disinfectants (must ensure dichloramine and trichloramine are not formed); less effective against viruses than other disinfectant processes; can create nitrification problems in distribution systems (Wilczak et al, 1996); toxic to fish (Seegert et al, 1979; Zillich, 1972).

Chlorine dioxide. This disinfectant is widely used in Europe. Generation usually involves the reaction of sodium chlorite with gaseous chlorine, hypochlorous acid, or hydrochloric acid.

Advantages. Minimized production of THMs and HAAs.

Disadvantages. Does not maintain a residual; requires secondary disinfection; safety concerns with sodium chlorite; can form by-products, including mutagenic compounds (such as MX and BMX), chlorates, and chlorites (Richardson, 2005); difficult to generate onsite; may produce a cat urine–type odor in the treated water; banned in some states.

UV light. Defined as electromagnetic radiation having a wavelength between 100 and 400 nm, UV light has been more commonly known as a means of disinfecting wastewater. Recently, because of its effectiveness for inactivatiing *Cryptosporidium* (Vrijenhoek et al, 1998), *Giardia*, bacteria, and viruses, UV has gained a much broader appeal for drinking water applications.

Advantages. Excellent disinfection for a wide variety of microbes; no DBPs produced; no chemical

TABLE 1 Capital cost comparisons—2005 and 2009

Treatment Technology	Capacity Cost—$					
	1 mgd		17 mgd		76 mgd	
	2005	2009	2005	2009	2005	2009
Alternate disinfectants						
Chloramine	53,396	62,608	98,772	113,899	397,173	451,036
Chlorine dioxide	40,035	47,531	268,223	302,344	603,425	683,678
UV disinfection	317,091	359,359	1,418,926	1,625,710	3,569,168	4,078,398
Ozone	804,614	974,973	3,946,957	4,865,079	12,628,950	15,996,225
Organic removal technologies						
Granular activated carbon (annual exchange)	783,808	863,696	6,140,593	6,902,107	18,311,317	20,481,136
Nanofiltration	912,423	1,057,344	15,546,118	17,948,220	57,558,238	67,328,295
Microfiltration/ultrafiltration	1,594,911	1,786,445	15,991,348	17,940,217	61,150,358	69,100,740

TABLE 2 Operations and maintenance cost comparisons—2005 and 2009

Treatment Technology	Capacity Cost—$					
	1 mgd		17 mgd		76 mgd	
	2005	2009	2005	2009	2005	2009
Alternate disinfectants						
Chloramine	4,443	4,861	11,333	13,528	31,538	41,078
Chlorine dioxide	18,571	21,217	35,939	41,818	87,061	102,220
UV disinfection	9,016	10,855	22,908	26,871	66,755	78,023
Ozone	76,470	91,862	455,559	652,134	1,974,401	2,906,241
Organic removal technologies						
Granular activated carbon (annual exchange)	57,078	61,531	227,710	251,037	709,287	777,712
Nanofiltration	112,309	133,392	1,780,761	2,161,229	7,914,024	9,684,873
Microfiltration/ultrafiltration	69,214	78,573	786,427	902,132	3,301,730	3,800,074

TABLE 3 Annual costs (based on a 10-year life cycle)—2005 and 2009

Treatment Technology*	Capacity Cost—$					
	1 mgd		17 mgd		76 mgd	
	2005	2009	2005	2009	2005	2009
Alternate disinfectants						
Chloramine	9,800	11,122	21,210	24,918	70,800	86,182
Chlorine dioxide	22,600	25,970	62,700	72,052	147,300	170,588
UV disinfection	40,200	46,791	164,800	189,442	423,700	485,863
Ozone	156,900	189,359	850,300	1,138,642	3,237,000	4,505,864
Organic removal technologies						
Granular activated carbon (annual exchange)†	135,500	147,900	841,100	941,248	2,539,000	2,825,826
Nanofiltration	203,000	239,126	3,326,000	3,956,051	13,660,000	16,417,703
Microfiltration/ultrafiltration	228,700	257,218	2,385,000	2,696,154	9,420,000	10,710,148

*Additional details regarding each treatment technology are available from the author upon request.
†Recent developments regarding the custom reactivation of activated carbon would result in decreases of approximately 20% in the operations and maintenance costs for that technology versus what is shown in Tables 2 and 3 for 2009.

safety concerns; efficiency is not sensitive to pH or temperature.

Disadvantages. No residual disinfection produced; requires secondary disinfection; efficiency is compromised by turbid water; some replacement parts periodically required.

Ozone. Typically generated by passing filtered, dehumidified air through a high-voltage electric field, ozone has a long history of effectively disinfecting drinking water.

Advantages. High disinfection efficiency; easily produced; produces fewer THMs or HAAs if used to offset a portion of chlorine disinfection.

Disadvantages. Produces no residual; requires secondary disinfection; forms bromate if bromides are present in the water (Weinberg et al, 2002); cannot be stored because of decay back to oxygen; potential for trihalonitromethane formation; health risk, requires monitoring when producing; breaks down organics, creating the potential for biogrowth in the distribution system; potential formaldehydes formation (Weinberg et al, 2002); expensive compared with other alternative disinfectant technologies.

ORGANIC REMOVAL TECHNOLOGIES SHOULD BE PAIRED WITH A DISINFECTANT SWITCH

Switching disinfectants in the absence of additional treatment is unlikely to be an effective long-term solution for the control of DBPs in drinking water. This is because most alternative disinfectants have negative side effects, including the formation of emerging DBPs likely to be regulated in the future. Technologies that target the removal of compounds that serve as precursors for the formation of DBPs can offer the best potential for overall water quality improvement.

Organic removal technologies can offer additional treatment benefits aside from the reduction of DBPs, but they will result in higher costs than a change of disinfectant alone. A number of treatment technologies have been shown to be effective in the reduction of DBP precursor compounds. Several of the more common are described in the following sections.

Other lesser known treatment technologies can be considered for NOM removal, but are not included because of limited information. Piloting would be advisable before committing to a technology without a proven history in a variety of applications.

Activated carbon adsorption. Used in fixed beds of granular carbon or added as powdered carbon to an agitated tank, adsorption technology is well known for its effectiveness for organic removal and is considered best available treatment (BAT) for many targeted organics as well as taste, odor, and color. There are few data regarding the effectiveness of this technology for *Cryptosporidium* removal, but it is believed that removal via activated carbon adsorption would likely be similar to that achieved with conventional granular media filtration.

Advantages. Known to effectively reduce NOM, tastes, odors, and color; BAT for THMs and HAAs; effective for removal of many endocrine disrupting and pharmaceutical chemicals; simple to operate and maintain; spent granular product can be reactivated and reused, further reducing cost; can remove DBPs formed by prechlorination treatment; generally cost-effective in relation to other processes.

Disadvantages. Does not remove inorganic bromides; depletes oxidizers used for predisinfection; pretreatment to remove solids may be required for treatment of surface water; effectiveness is a function of molecular size, polarizability, and ionic strength of the organics in the water.

Microfiltration and ultrafiltration. These low-pressure membrane filtration processes are commonly used for high-efficiency particulate removal applications. Operating at 10–30 psi, microfiltration has a nominal pore size of 0.2 μm and ultrafiltration has a nominal pore size of 0.01 μm. These treatment processes remove organics above 10,000 molecular weight.

Advantages. Simple to operate and automate; effective for particle and microbial removal.

Disadvantages. Limited effectiveness for DBP precursors when used alone; may require the addition of coagulant or powdered activated carbon to achieve desired treatment; ineffective for color, tastes, odors, and endocrin disrupting chemicals; expensive even at smaller installations; significant residual waste for disposal.

TABLE 4 USEPA 2005 cost elements

Commodity	Cost—$
Electricity	0.076/kW·h
Diesel	1.48/gal
Natural gas	0.009/scf
Building energy use	102.6 kW/sq ft/year
Alum	300/ton
Chlorine (cylinder)	600
Ferric chloride	400/ton
Lime (hydrated)	110/ton
Polymer	1.00/lb
Sodium hexametaphosphate	1,300/ton
Sodium hydroxide	350/ton
Sodium chloride	100/ton
Sulfuric acid	100/ton
Granular activated carbon	1.00–1.20/lb

Nanofiltration and reverse osmosis. These higher-pressure membrane processes are well known for the extremely high purity they are capable of producing. Operating at 90 psi, nanofiltration has a nominal pore size of 0.001 μm.

Advantages. Effective for water softening; effective for microbe removal; shown to achieve 50–90% removal of total organic carbon, depending on its molecular size, shape, chemical characteristics, and ionic character.

Disadvantages. Very expensive technology; prone to fouling in surface water treatment; no more effective for microbe removal than ultrafiltration; adsorption of organics by the membrane can be irreversible and decrease membrane life; significant wastewater volume to be treated.

Enhanced oxidation. Using UV light in combination with hydrogen peroxide or ozone, this technology serves to destroy much of the NOM by breaking chemical bonds between the

TABLE 5 2009 economic update

Product/Service	Commodity Code	February 2005 Index	February 2009 Index	Increase—%
Accommodations	721	129.1	139.7	8.2
Aluminum compounds	0613-0209	108.8	150.5	38.3
Building Cost Index (NAICS 235221)	N/A	100 (December 2004)	130.7 (January 2009)	30.7
Building Cost Index (Turner)	N/A	655	866	32.2
Capital equipment	N/A	143.9	157.4	9.4
Chemical and allied products	06	186.4	228.4	22.5
Chlorine, sodium hydroxide, and other alkali	0613-0302	100 (June 2005)	205.6	105.6
Concrete ingredients and related products	132	180.4	236.2	30.9
Electric machinery and equipment	117	113.4	113.8	0.4
Employee compensation per hour (private industry)	N/A	$24.17 (Q1, 2005)	$27.35 (Q4, 2008)	13.1
Engineering and scientific instruments	1185	177.8	193.1	8.6
Engineering services	54133	103.0	114.4	11.1
Environmental controls	1181	149.1	159.7	7.1
General purpose machinery and equipment	114	165.9	199.7	20.4
Heavy equipment leasing	532412	104.5	117.3	12.2
Industrial chemicals	061	179.2	226.2	26.2
Industrial commodities	N/A	153.6	170.9	11.3
Industrial electric power	0543	148.0	189.7	28.2
Industrial natural gas	0553	211.9	235.3	11.0
Inorganic acids	0613-0224	79.7	155.5 (November 2008)	95.1
Integrating and measuring instruments	1172	148.1	156.4	5.6
Legal services	5411	137.1	164.6	20.0
Lime	0613-0213	140.2	219.6	56.7
Medical and diagnostic laboratories	6215	104.2	108.3	3.9
Metal and metal products (iron and steel)	101	179.8	183.0	2.8
Metal valves (except fluid power)	1149-02	186.9	245.4	31.3
Miscellaneous general purpose equipment	1149	183.7	226.4	23.2
Natural sodium carbonate and sulfate	0613-0301	99.8 (March 2005)	174.7	75.0
No. 2 diesel fuel	0573-03	149.5	145.6	–2.6
Potassium and sodium compounds (except bleaches)	0613-0217	105.6	289.1	173.8
Process control instruments	1182	162.2	196.4	21.1
Pumps, compressors, and equipment	1141	175.4	212.8	21.3
Sodium hydroxide	0613-0108	145.9	N/A	N/A
Steel pipe and tube	1017-06	193.8	206.6	5.0
Sulfuric acid	0613-0232	166.7	254.8 (November 2008)	52.8
Synthetic ammonia	0652-0135	123.2	181.3	47.2
Transformers and power regulators	1174	145.2	205.9	41.8
Water treatment compounds	325998-A	152.1	182.8	20.1
Water treatment compounds	0679-0961	168.4	181.9	8.0

N/A—not applicable, Q—quarter

constituent atoms. The NOM is converted to CO_2 or a simpler organic compound that has less potential for DBP formation. This technology has also been effectively used to treat many synthetic organic compounds.

Advantages. Effective in reducing NOM in water; potential for destruction of endocrine disrupting chemicals in water; capability of *Cryptosporidium* and *Giardia* inactivation; no THM or HAA produced; no residual waste to dispose (Shin et al, 2000; Bolton Et al, 1998).

Disadvantages. The process is compromised by turbid water, may require pretreatment; requires chemical storage; produces no residual disinfectant; requires secondary disinfection; other DBP formation possible; some replacement parts are periodically required.

Enhanced coagulation. Many surface water treatment plants use chemical coagulation with alum, ferric chloride, or lime for the removal of suspended solids from the raw water. By increasing the coagulant dose and optimizing pH, coagulation can be adapted to the removal of DBP precursors (Bolton et al, 1998).

Advantages. Requires little additional capital equipment than that typically needed for turbidity removal; BAT for THMs and HAAs; can achieve 50% reduction in humic acids by forming insoluble humates; improved disinfection efficiency by reduced organic oxidant demand; some *Cryptosporidium* and *Giardia* removal; complements activated carbon treatment by removing high-molecular-weight, negatively charged organics.

Disadvantages. Larger sludge volumes created; increases coagulant use (up to five times that required for solid removal); optimum pH (5.5 for ferric chloride and alum) requires two pH adjustments; postprecipitation in distribution systems; corrosion potential in distribution systems; waters with high bromide

> Water utilities across the United States will soon face difficult choices as they formulate plans to comply with the requirements of the Stage 2 Disinfectants/Disinfection Byproducts Rule while working to continue controlling capital and operating costs.

TABLE 6 Capital cost factors and cost escalators

Cost Factor (Capital)	Escalator (Commodity Code)
Analyzer	Engineering and scientific instruments (1185)
Chemical feed system	Capital equipment (general BLS category, no code)
Discharge pipeline	Steel pipe (1017)
Effluent ozone quench	Environmental controls (1181)
Electrical and instrumentation	Process control instrumentation (1182)
Housing	Accommodations (721)
Land	Percentage of direct capital cost (varies with technology)
Operator training	Engineering services (54133)
Ozone contactor	Capital equipment
Ozone generation system	Capital equipment
Ozone off-gas destruction system	Environmental controls (1181)
Permitting	Percentage of capital premultiplier (varies with technology)
pH adjustment	Environmental controls (1181)
Piloting	Engineering services (54133)
Pipes and valves	Steel pipe (1017) + metal valve (1149-02)*
Process monitoring equipment	Process control instrumentation (1182)
Public education	Engineering services (54133)
Pumping	Pumps, compressors, and equipment (1141)
Scrubber	Environmental controls (1181)
Stocked spare parts	Miscellaneous general purpose equipment (1149)
Treatment equipment	Capital equipment (general BLS category, no code)
Ultraviolet reactors	Capital equipment (general BLS category, no code)

BLS—Bureau of Labor Statistics

*In determining the escalation of costs for pipes and valves an assumption will need to be made about the percentage of cost that will be related to each item individually and that portion escalated.

concentrationss can produce higher brominated DBPs; adds inorganics (manganese, aluminum, sulfate, chloride, and sodium) to the water supply; may increase floc fragility.

TREATMENT SYNERGIES ARE POSSIBLE

The effectiveness of most of the treatment technologies will be limited in some regard because of the diverse nature of NOM. Combinations of treatment technologies may prove to offer significant advantages in terms of cost-effective achievement of treatment goals. For example, combining the two technologies currently designated as BAT (USEPA, 2001) may provide a significant benefit over their individual performance.

Activated carbon adsorption is most effective for the portion of NOM composed of smaller-size organic compounds without charged functional groups (DeSilva, 2000). Conversely, enhanced coagulation is generally considered to be most effective for the portion of NOM composed of large organic molecules with negatively charged functional groups (Uyak, 2007). By using a combination of technologies, the percentage reduction of DBP precursor compounds can be increased and possibly maintained for a longer duration. Combining treatment technologies with an alternative disinfectant may be a course of action worth considering for many source water applications.

CAPITAL AND OPERATING COSTS ARE CRITICAL CONSIDERATIONS

In uncertain economic times, capital and operating costs are vital considerations in the selection of best available control technologies. Although the specific capital costs for different technologies can differ greatly, general estimates have been used to account for project costs aside from the direct costs of the capital equipment. The past few years have seen significant cost increases, particularly for commodity chemicals. Rapid international growth along with production capacity limitations have resulted in significant cost increases for most water treatment chemicals. Rising fuel and energy prices have added to chemical costs as well as transportation costs. Steel and other building materials costs have also risen during this period.

In December 2005, USEPA published cost estimates (along with their component cost elements) for many of the treatment technologies that can be used to assess the cost of compliance with the Stage 2 D/DBPR (USEPA, 2001). These estimates, which include both capital and operating costs, are summarized in Tables 1 and 2, respectively; each table has been updated to also provide 2009 costs for each parameter. A simple 10-year life cycle cost analysis for 2005 (and updated here for 2009) is given in Table 3. USEPA's 2005 cost elements are listed in Table 4.

Using the cost escalations of the matching elements contained in the 2005 USEPA publication, a revised set of projected capital and operating costs for the respective technologies was generated. As the 2009 data in Tables 1–3 show, taken as a whole these price differences do not change the comparative economics of the respective technologies.

Capital costs include major equipment cost, pilot-testing, permitting, land cost, operator training, housing, pipes and valves, instrumentation and control, chemical addition systems, and on-line analyzers. As the major equipment is priced, general additions are included for initial budgeting. Typically, the following can be assumed:

- add 20% for site work and installation,
- add 10% for electrical and instrumentation and control (more if full automation is needed),
- add 20% for engineering and administration, and
- add 20% for contingencies.

Initial operations and maintenance costs (labor, power, maintenance materials, performance monitoring, media replacement, chemicals) can be estimated by using the estimates for annual chemical costs and power costs for major equipment and by adding 3% of capital cost for annual materials, labor, and maintenance.

Over the past few years, there have been several changes in costs for both products and services. Calculated from US Bureau of Labor Statistics data, values for products, services, and cost indexes for both 2005 and 2009 are shown in Table 5.

In the nearly five-year period since the initial development of USEPA's cost estimates, some capital and operating costs have changed significantly. The largest price increases

TABLE 7 Operations and maintenance cost factors and cost escalators

Cost Factor (Operations & Maintenance)	Escalator (Commodity Code)
Chemicals (activated carbon)	Vendor quote
Chemicals (antiscale)	Water treatment compounds (0679-0961)
Chemicals (chloramine)	Synthetic ammonia (0652-0135) + chlorine (0613-0302)
Chemicals (ClO_2)	Chlorine (0613-0302)
Electricity	Industrial electric power (0543)
Labor	Employee compensation per hour (private industry)
Maintenance materials	Miscellaneous general purpose equipment (1149)
Parts	Miscellaneous general purpose equipment (1149)
Performance monitoring	Medical and diagnostic laboratory (6215)
Tank lease	Heavy equipment lease (532412)

have been in commodity chemicals as a result of increasing demand from developing countries and in non-water-treatment industries, and limitations in manufacturing capacity. Costs for water treatment chemicals have increased at a somewhat slower pace than those for commodity chemicals. Energy prices have experienced significant fluctuations during this period, and they currently stand substantially below their peak levels. General prices for wages and other services have increased slowly by comparison. Tables 6 and 7 provide escalators for many of the components used to derive the projected 2009 capital and operating costs for the various treatment technologies.

SUMMARY

Ensuring safe drinking water supplies is an ongoing process. As new health risks are identified, they must be addressed. The solutions are seldom simple or inexpensive. Water utilities will soon be challenged to meet DBP regulations without creating additional health concerns, which may be the case with some of the alternative disinfectants (Krasner et al, 2006; Weinberg et al, 2002). Clearly, a number of treatment alternatives are available, and careful assessment must be made to determine which ones will provide the best performance for DBP control and other water quality objectives. Because of increasing costs, particularly those for commodity chemicals, it will be equally important to carefully evaluate the different treatments and perhaps combinations of treatments along with the respective vendors in order to ensure that an effective treatment is guaranteed while costs are kept reasonable.

Although the capital and operating costs for all of the technologies have increased from 2005 to 2009, the relative rankings of the technologies on an economic basis remain the same. On the basis of this reexamination of the technologies currently available to address compliance with the Stage 2 D/DBPR, it seems clear that precursor control—versus switching to an alternate disinfectant—is the preferred primary approach to compliance. Further, the data suggest that among the precursor technologies examined, activated carbon continues to be the most cost-effective method available.

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Detailed information regarding the alternative disinfectants and technologies discussed in this article is available from the author. E-mail your request to alroy@comcast.net.

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CATEGORY 1 - GREEN INFRASTRUCTURE

1.1 FTTP Green Roof

Roof Size	14,600	SF
Annual Precipitation	42	inches
Total Volume of Rain	382,199	gallons
Unit cost for wastewater treatment	$6.76	per 1,000 gallons
Amount Retained on Roof	50	percent
Amount Retained on Roof	191,099	gallons
Savings per year	$1,292	
Total heating requirements	87	kW
Hours per day operated	12	hrs
Number of months used	8	mos
Unit Cost for power	0.05	kWh
Total kWh used per year	250,560	kWh
Total cost for power	$12,528	
Estimated savings	10	percent
Amount of KW saved	25,056	kWh
Savings per year	$1,253	

1.2 FTTP Rain Garden

Area size	50,000	SF
Annual Precipitation	42	inches
Total Volume of Rain	1,308,901	gallons
Unit cost for wastewater treatment	$6.76	per 1,000 gallons
Amount Retained by grass	50	percent
Additional amount retained by garden	30	percent
Amount Retained by grass	654,450	gallons
Additional amount retained by garden	196,335	gallons
Savings per year	$1,327	

1.3 TMTP Green Roof

Roof Size	16,000	SF
Annual Precipitation	42	inches
Total Volume of Rain	418,848	gallons
Unit cost for wastewater treatment	$6.76	per 1,000 gallons
Amount Retained on Roof	50	percent
Amount Retained on Roof	209,424	gallons
Savings per year	$1,416	
Total heating requirements	87	kW
Hours per day operated	12	hrs
Number of months used	8	mos
Unit Cost for power	0.05	kWh
Total kWh used per year	250,560	kWh
Total cost for power	$12,528	
Estimated savings	10	percent
Amount of KW saved	25,056	kWh
Savings per year	$1,253	

CATEGORY 2 - WATER EFFICIENCY

2.1 FTTP EQ Basin

Amount sent to basin	191,099	gallons
Size of metal roof	3200	SF
Annual Precipitation	42	inches
Total Volume of Rain	83,770	gallons
Contactor backwash rate	6	gpm/SF
Contactor size	880	SF
Time for backwash, post change out	120	minutes
Time for backwash, monthly routine	5	minutes
Number of backwashes a year, post change out	8	events
Number of monthly routine, 12 x 8	96	events
Total volume of contactor backwash water	7,603,200	gallons
Contactor to waste rate	6	gpm/SF
Time for contactor to waste	60	minutes
Number of events	104	events
Total volume of contactor to waste water	32,947,200	gallons
Slurry water use per changout	50,000	gallons
Number of chang out events, 8	400,000	gallons
Total all flows into EQ basin	41,034,170	gallons
Unit cost for wastewater treatment	$6.76	per 1,000 gallons
Unit cost for pumping	$0.07	per 1,000 gallons
Total savings for wastewater treatment	$277,391	
Total savings for pumping	$2,872	

2.2 MPTP Reservoir Recycled Water

Contactor backwash rate	6	gpm/SF
Contactor size	624	SF
Time for backwash, post change out	120	minutes
Time for backwash, monthly routine	5	minutes
Number of backwashes a year, post change out	3	events
Number of monthly routine, 12 x 3	36	events
Total volume of contactor backwash water	2,021,760	gallons
Contactor to waste rate	6	gpm/SF
Time for contactor to waste	60	minutes
Number of events	39	events
Total volume of contactor to waste water	8,760,960	gallons
Slurry water use per changout	30,000	gallons
Number of chang out events, 3	90,000	gallons
Total all flows to Reservoir	10,872,720	gallons
Total savings for wastewater treatment	$73,500	
Total savings for pumping	$761	

2.3 TMTP EQ Basin

Contactor backwash rate	1000	gpm
Number of vessels	14	
Time for backwash, post change out	30	minutes
Time for backwash, monthly routine	5	minutes
Number of backwashes a year, post change out	14	events
Number of monthly routine, 12 x 14	168	events
Total volume of contactor backwash water	1,260,000	gallons
Contactor to waste rate	500	gpm
Time for contactor to waste	60	minutes
Number of events	182	events
Total volume of contactor to waste water	5,460,000	gallons
Slurry water use per changout	20,000	gallons
Number of chang out events, 14	280,000	gallons
Total all flows to Reservoir	7,000,000	gallons
Total savings for wastewater treatment	$47,320	
Total savings for pumping	$490	

2.4 FTTP Air Scour Blower

Contactor backwash rate	6	gpm/SF
Contactor size	880	SF
Time for backwash, post change out	120	minutes
Total volume of contactor backwash water	5,068,800	gallons
Cost to treat water that would be wasted	$2.97	per 1,000 gallons
Total savings for wastewater treatment	$15,054	

CATEGORY 3 - ENERGY EFFICIENCY

Taylor Mill Treatment Plant Advanced Treatment					
Count	**Location**	**Watts**	**Hrs per week**	**kWh per Year**	**$ per Year**
1	lab closet	69	2	7	$0
9	GAC PS	150	60	4,212	$211
4		73	168	2,551	$128
2	LF-AE	73	168	1,275	$64
2		36	168	629	$31
1	LF-BE	36	168	314	$16
2		60	168	1,048	$52
12		340	168	35,643	$1,782
8	LF-DE	340	168	23,762	$1,188
2		297	168	5,189	$259
3	LF-GE	297	168	7,784	$389
18		198	168	31,135	$1,557
13		123	168	13,969	$698
9	LF-JE	123	168	9,671	$484
6		93	168	4,875	$244
3	LF-KE	93	168	2,437	$122
18		60	168	9,435	$472
19	LF-ME	60	168	9,959	$498
4	LF-RE	56	168	1,957	$98
15	outside	185	70	10,101	$505
3	outside	198	70	2,162	$108
11	exit	0.92	168	88	$4
6	exit	0.92	168	48	$2
			TOTAL	**178,252**	**$8,913**

Fort Thomas Treatment Plant Advanced Treatment						
Fixture #	**Count**	**Location**	**Watts**	**hrs per week**	**kWh per year**	**$ per Year**
1	225	each floor	32	168	62,899	$3,145
2	5	pipe gallery	32	168	1,398	$70
3	35	each floor	100	168	30,576	$1,529
4	20	each floor	32	168	5,591	$280
5	7	pipe gallery	32	168	1,957	$98
6	12	mechanical	32	168	3,355	$168
8	6	exit	1	168	52	$3
9	1	exit	3	168	26	$1
11	1	exit	1	168	9	$0
12	1	roof	150	70	546	$27
13	1	roof	100	70	364	$18
				TOTAL	**106,773**	**$5,339**

Memorial Parkway Treatment Plant Advanced Treatment						
Fixture #	**Count**	**Location**	**Watts**	**hrs per week**	**kWh per year**	**$ per Year**
1	143		32	168	39,976	$1,999
2	5		32	168	1,398	$70
3	14		150	168	18,346	$917
5	10		1	168	87	$4
6	1		3	168	26	$1
8	1	outside	250	70	910	$46
				TOTAL	**60,743**	**$3,037**

Climate - Cincinnati - Ohio

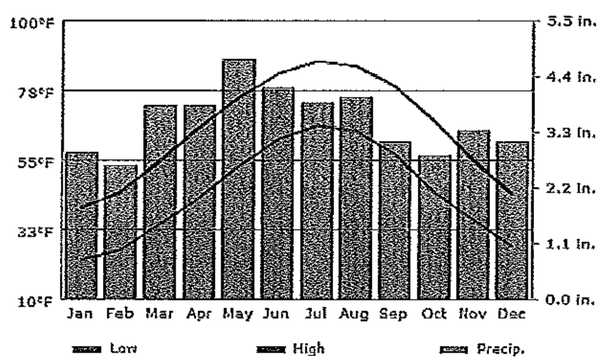
Temperature - Precipitation - Sunshine C | F

	Jan	Feb	March	April	May	June
Average high in °F	39	44	55	65	75	83
Average low in °F	22	26	34	43	53	62
Av. precipitation - inch	2.87	2.64	3.82	3.82	4.72	4.17
Days with precip.	13	11	13	12	12	13
Hours of sunshine	115	137	186	222	273	309

	July	Aug	Sep	Oct	Nov	Dec
Average high in °F	87	85	79	67	55	44
Average low in °F	66	64	57	44	36	27
Av. precipitation - inch	3.86	3.98	3.11	2.83	3.31	3.11
Days with precip.	10	9	9	9	10	11
Hours of sunshine	323	295	253	205	138	118

Free climate chart on your website

Cincinnati Climate Graph - Ohio Climate Chart



Totals and averages

Annual average high temperature	64.8 °F
Annual average low temperature	44.5 °F
Average temperature	54.6 °F
Average annual precipitation	42.2 in.
Days per year with precipitation	132 d.
Average annual hours of sunshine	2574 h.

Map of Cincinnati